

# UUV Operations to Characterize Circulation and Morphology of Tidal Flats

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## LONG-TERM GOALS

We propose to continue our Unmanned Underwater Vehicle (UUV) work to investigate circulation and bottom morphology in tidal flats and surrounding environments. While these areas have traditionally been difficult to sample, UUVs with advanced sensor technology afford the opportunity to systematically study the dynamic components of these systems. Our deployments of the REMUS UUV in coastal waters of the Pacific, Atlantic and Gulf of Mexico demonstrate the ability of this platform to operate routinely in VSW environments, including harbors, estuaries, and the near shore/surf zone transition. Highly resolved measurements of circulation patterns, in water components, bottom topography and characterization will be taken in the specific study sites chosen for this DRI. These data will support the general goals of this DRI in identifying and advancing our understanding of mechanisms for morphologic change in tidal mud flats.

## OBJECTIVES

The objective of this work is to improve characterization of tidal mud flats and surrounding areas with the use of UUV systems. These measurements would be made in conjunction/collaboration with other participants to determine the processes and parameters governing change in these shallow environments, and improve model parameterization and performance. Specifically we propose to 1) Deploy UUV systems at a number of resolutions in the study site to obtain regional and local bathymetry. These data will be used for initial model parameterization. Repeat measurements will also allow for change analysis of the tidal flats morphology and geotechnical stability. (2) Use side scan sonar to map and evaluate bottom roughness and morphology, and change in those parameters over time. (3) Quantify circulation patterns in the study area with deployments targeted at resolving the influence of tidal forcing. These measurements will be required to track flow of through the system and the influence on morphology and stability. (4) Define the boundary conditions of the study area. In addition to flow on the tidal flats, it will be important to also assess the forcing from the boundaries, which may or may not be in very shallow water. These data are critical for coastal/estuarine circulation models. The UUV can help define the inputs and outputs of the system for initiation and validation of the models. (5) Measure *in situ* physical properties in the study area. Diurnal surface warming and influence from riverine inputs would be expected to significantly alter local densities. Changes in density over relatively short time and space scales would be expected to the flow patterns in areas with little wind, and effect the distribution and advection of sediment in the system. (6) Determine optical properties in the study area. The addition of optical proxies for sedimentation

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measured simultaneously with currents by the UUV allows for examining the local sources and sinks of sediment, the types of sediment, and changes over time in the tidal flat morphology. Additional optical measurements of CDOM would be especially relevant as these measurements would be able to identify source signatures, and may act as tracers for your modeling efforts.

## **APPROACH**

The following section will take each objective and provide some detail on the approach for data collection and relevance to the program.

**Deploy UUV systems at a number of resolutions in the tidal flat system to obtain regional and local bathymetry.** This would entail flying the vehicle in a mow-the-lawn pattern at a fairly shallow depth to get good depth information. The resolutions would be chosen based on programmatic needs and depend on features of interest. The along track horizontal resolution would be on the order of 20 cm with the rows spacing from 1-100 m. These data would be used for initial model parameterization and or in areas of interest that can not be readily accessed by other means. Data from each mission would be available approximately 30 minutes after vehicle retrieval. Data from all the sensors would be available. The side scan sonar would likely be turned off for these missions to increase vehicle duration and to avoid problematic data as the varying depth would influence data analysis. Repeat measurements over the course of the experiment will also allow for change analysis of the tidal flats morphology and geotechnical stability.

**Use side scan sonar to map and evaluate bottom roughness and morphology, and change in those parameters over time.** These mission would be either transects or a series of transects programmed in a grid and probably flown at a constant altitude off the bottom. Detail from the side scan sonar can reveal features at scales > 5 cm and based on reflectance can be qualitatively categorized from mud to sand to coble to rocks to large rock outcroppings (Figure 3). Details of animals, features and targets of interest will also be elucidated.

**Quantify circulation patterns in the study area with deployments targeted at resolving the influence of tidal forcing.** Transect deployments at fixed depths have provided the best data on currents to date. In addition, repeat missions over the same area improve the sampling statistics and resolve the tidal velocities well. These measurements will be required to track flow of through the system and the influence on morphology and stability. One would expect both tides and river flow to have the greatest impacts to morphology (in the absence of storms) and would be the focus of this work.

**Define the boundary conditions of the study area.** In addition to flow on the tidal flats, it will be important to also assess the forcing from the boundaries, which may or may not be in very shallow water. These data would be critical for coastal/estuarine circulation models. A mission approach to this question would entail a repeated box around the location of interest and or repeat transects along boundaries to examine vertical current structure over tidal cycles, for example. The UUV can help define the inputs and outputs of the system for initiation and validation of the models.

**Measure *in situ* physical properties in the study area.** Diurnal surface warming and influence from the riverine input would be expected to significantly alter local densities. Changes in density over relatively short time and space scales would be expected. This could change the flow patterns in areas

with little wind, and effect the distribution and advection of sediment in the system. All modes of operation would support data collection and u, v, w, t model inputs.

**Determine optical properties in the study area.** Although not explicit in the program goals, the addition of optical measurements in conjunction with the measurements highlighted above may provide value added information. Optical proxies for sedimentation measured simultaneously with currents by the UUV allows for examining the local sources and sinks of sediment, potentially the types of sediment, and changes over time in the tidal flat morphology. Additional optical measurements of CDOM would be especially relevant as these measurements would be able to identify source signatures, and may act as tracers for your modeling efforts.

**Data integration into models.** Data from the UUV will be available for model inputs approximately 30 minutes after vehicle retrieval. Many of our previous REMUS deployments have been in support of modeling efforts. These include efforts with the ROMS model for ONR DRI (Adaptive Ocean Sampling Network II, Layered Organization in the Coastal Ocean) and MURI (ASAP) projects on both the east and west coasts of the U.S. in collaboration with Rutgers, UCLA and JPL. In these efforts we have used the UUV data for near real-time data assimilation, performance and prediction metrics, and adaptive model-driven mission planning. In addition we have recently collaborated with the Pacific Northwest National Laboratory (L. Hibler and A. Maxwell) as part of ONR's Coastal Environmental Effects program providing inputs into their DELFT model. Specifically, we have incorporated in a DELFT application as configuration data (bathymetry) and calibration data (water quality – in this case a Rh-WT dye tracer). From this, we have developed experience with data fusion and georeferencing of field datasets for incorporation into the circulation and transport model. We propose to partner with other DRI investigators, who would use UUV data in similar ways.

## **WORK COMPLETED**

This work was a new start in FY07 for the purposes of defining the science plan for the DRI effort towards planning pilot studies. Two planning meetings were attended, one in Honolulu, HI (March, 2007) and the other in Incheon, Republic of Korea (June, 2007). In addition to contributing to the science plan through a series of working groups, these meetings were an opportunity to refine approaches (above). In particular, use of UUV data in model parameterization and validation were explored further.

In May, 2007 testing of some of the approaches (above) were conducted in Morro Bay tidal flats with the UUV, an environment similar to the morphologies seen in Korea. The missions were designed to obtain bathymetry from extremely shallow environments in a tidal regime in an effort to demonstrate the UUV capabilities and bridge the gap between in water bathymetric approaches (multibeam) and aerial approaches (i.e. LIDAR).

## **RESULTS**

This work was a new start in FY07 for the purposes of defining the science plan for the DRI effort towards planning pilot studies. In addition to the contribution to the science plan. The UUV demonstrations in Morro Bay, CA demonstrated the ability of the REMUS-100 system to make quantitative measures in these dynamic shallow environments and laid the groundwork for future pilot studies. These were the first applications of this type with a REMUS-100 system. Lessons were

learned from this experience, and modifications are being made to the vehicle logic to improve performance.

### **IMPACT/APPLICATIONS**

Deployments will influence future deployments and may provide a reliable tool for sampling these environments to address the science objectives of the tidal flats DRI.

### **RELATED PROJECTS**

Related to an effort in collaboration with L. Hilber to work up the data on ONR's Coastal Environmental Effects program providing UUV inputs into and validation data sets for the DELFT model.

### **HONORS/AWARDS/PRIZES**

Mark A. Moline, California Polytechnic State University, 2006-2007 Distinguished Scholarship Award